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3.2 EVERGLADES AGRICULTURAL AREA

3.2.1 Introduction

The entire area whose primary supplemental water supply needs are met by Lake Okeechobee is collectively known as the Lake Okeechobee Service Area (LOSA). This area is comprised of several major basins including the Everglades Agricultural Area (EAA), the Caloosahatchee River (C-43) Basin, the St. Lucie River (C-44) Basin and many other, smaller basins located around the Lake (Figure 3.2.1.1). In this region, the majority of the supplemental demands on the regional system are for the purpose of agricultural irrigation. In the SFWMM, LOSA basins are handled using two distinct modeling approaches as dictated by data availability issues. The EAA, L-8 and S-236 Basins are modeled as part of the distributed 2-mile x 2-mile gridded system. In contrast, the C-43, C-44, S4 and other basins are modeled using a lumped system water-budget approach. This section focuses on the methodologies used in simulating the EAA within the SFWMM while Section 3.3 covers the simulation of lumped LOSA basins and management policies that affect LOSA as a whole. Topics addressed in this section include: calculation of ET in the EAA as it relates to the estimation of runoff and demand (irrigation requirement) in the EAA; routing of runoff within the EAA, including canal conveyance considerations; and additional complexities of system components and management in the EAA, primarily above ground storage features including reservoirs and Stormwater Treatment Areas (STAs).

General Description

The Everglades Agricultural Area (EAA) encompasses an area south and southeast of Lake Okeechobee (Figure 3.2.1.2), covering approximately 593,000 acres of land of which 468,000 acres are in agricultural production (1988 land use cover information). A strong interaction exists between the hydrologic and management processes in the Everglades Agricultural Area. Of the area in agricultural production, about eighty percent is sugar cane. The four primary conveyance canals within the EAA are the Miami, North New River, Hillsboro and West Palm Beach Canals. They are used both for water supply and flood control purposes. The major structures in the EAA are S-3/S-354, S-2/S-351, S-352, S-5A, S-6, S-7, and S-8 (Figure 3.2.1.2).

The Rotenberger Tract and Holey Land, although part of the Miami Canal Basin, are separated from the irrigated areas by levees, and thus, are treated as separate subbasins in the model. The following discussion will focus on the Miami, North New River/Hillsboro and West Palm Beach Canal Basins. The 298 Districts, as shown in Figure 3.2.1.2, will be discussed in Section 3.3.8. Figure 3.2.1.3 conceptualizes inflows and outflows from the EAA. The SFWMM simulates discharges at all inlet and outlet structures shown in Figure 3.2.1.3 except G-88 and G-136 at which discharges are estimated separately (refer to Section 2.7).

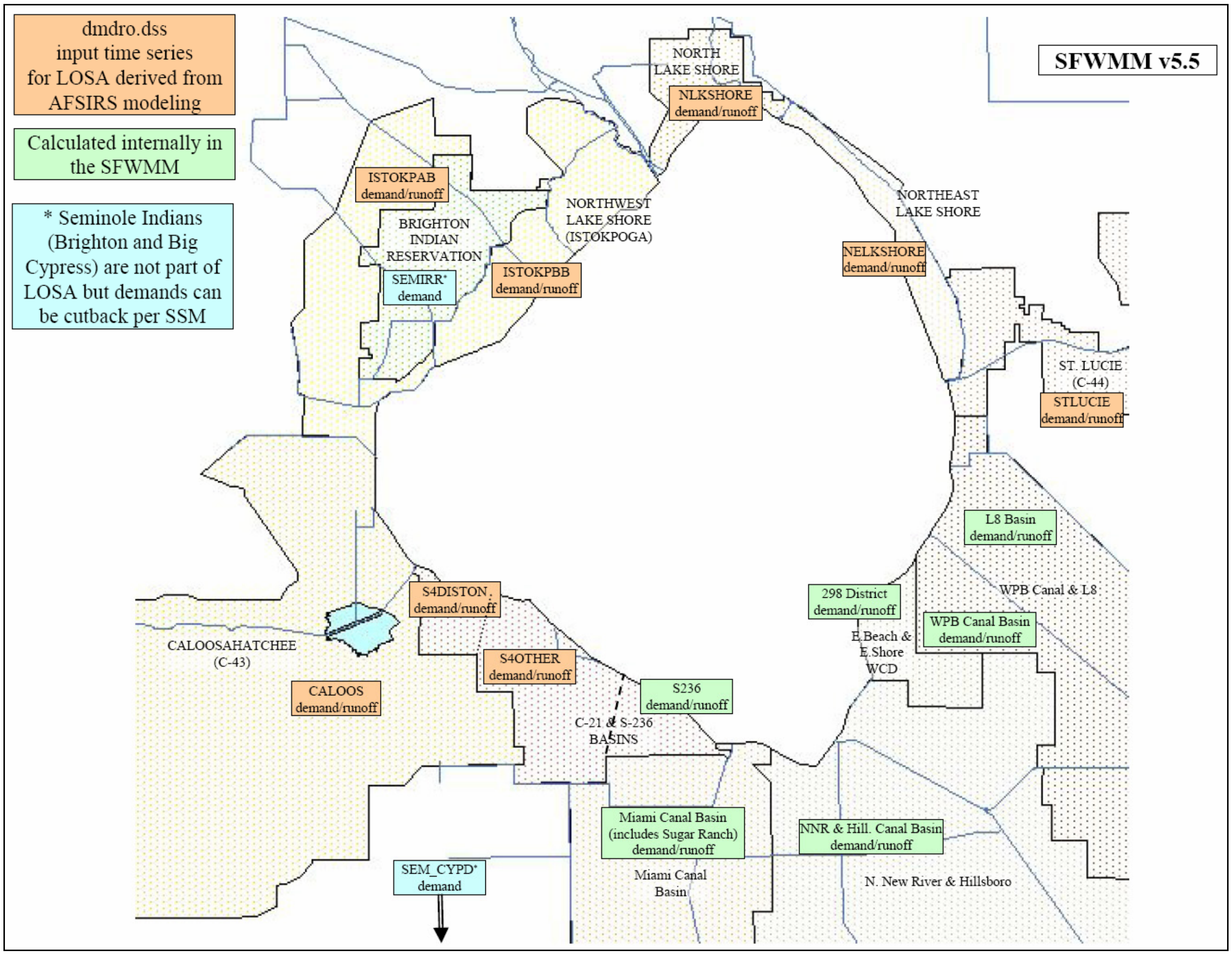

Figure 3.2.1.1 LOSA Basins around Lake Okeechobee

The unique characteristics of the EAA are as follows:

1. Extensive field-scale management operations within the EAA are simplified such that they fit within the regional-scale modeling framework of the SFWMM. Water levels within the EAA are well-maintained below land surface due to seepage irrigation. Thus, overland flow is not calculated between grid cells within the EAA although infiltration, evapotranspiration and groundwater flow are still simulated as distributed processes within the same area.
2. Discharges from the Lake into the EAA and into the WCAs through the EAA canals are influenced by operating rules in the EAA, as well as by those in Lake Okeechobee and the Water Conservation Areas.
3. The amount of water that can flow through the EAA is constrained by EAA canal conveyance characteristics, and local runoff and demand conditions.
4. Flow-through capacity along an EAA canal, i.e., the amount of Lake water that can be delivered south into the Water Conservation Areas, depends on EAA canal conveyance characteristics. The latter, in turn, is a function of the EAA canal water surface profile. Therefore, a hydrodynamically-based routing procedure where the water surface profile and corresponding discharge is calculated for the EAA is necessary in order to account for the daily variation of EAA flow-through capacity. This procedure is different from the

water budget approach applied to non-EAA canals where a hydraulic grade line with time-invariant slope is assumed.

5. Limited or sparse stage data exists for the interior part of the EAA such that calibration by matching historical stages is not possible at this point in time.

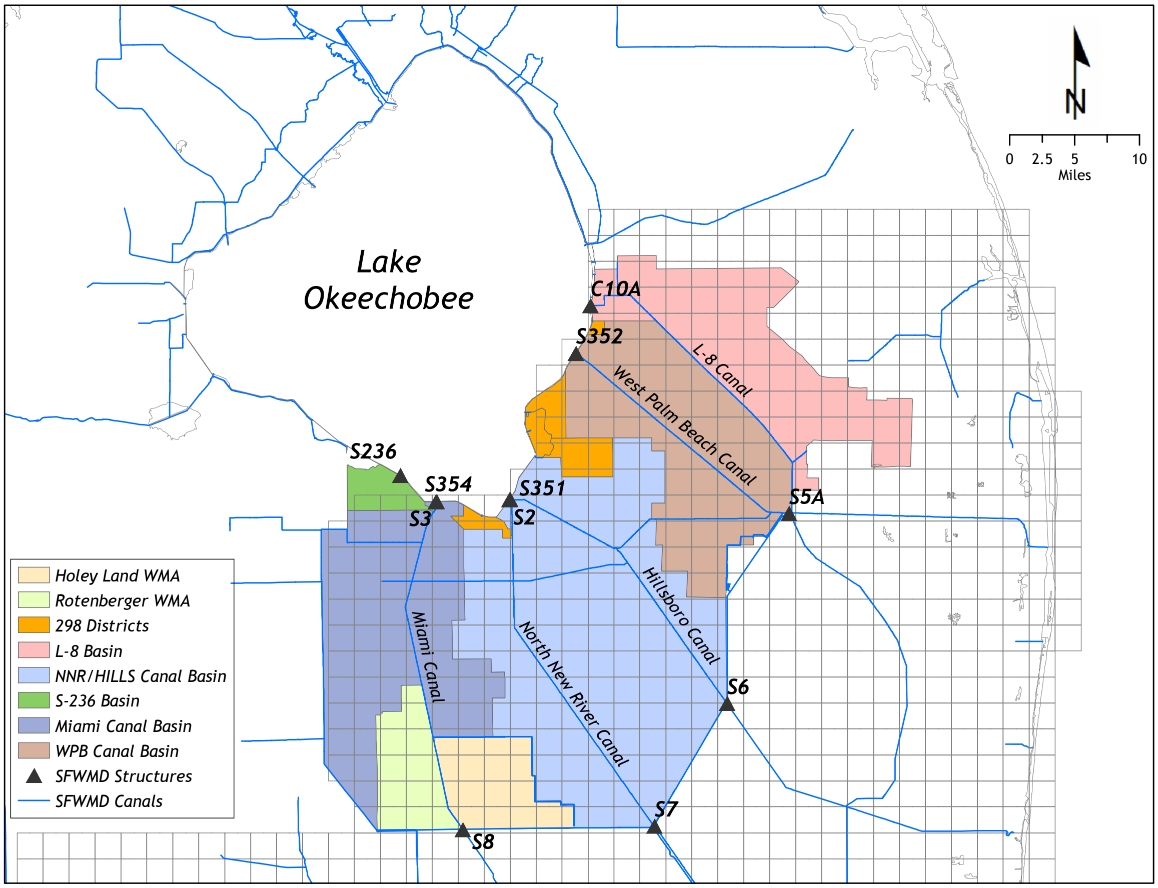

Figure 3.2.1.2 SFWMM Grid Superimposed on Major Basins in the EAA

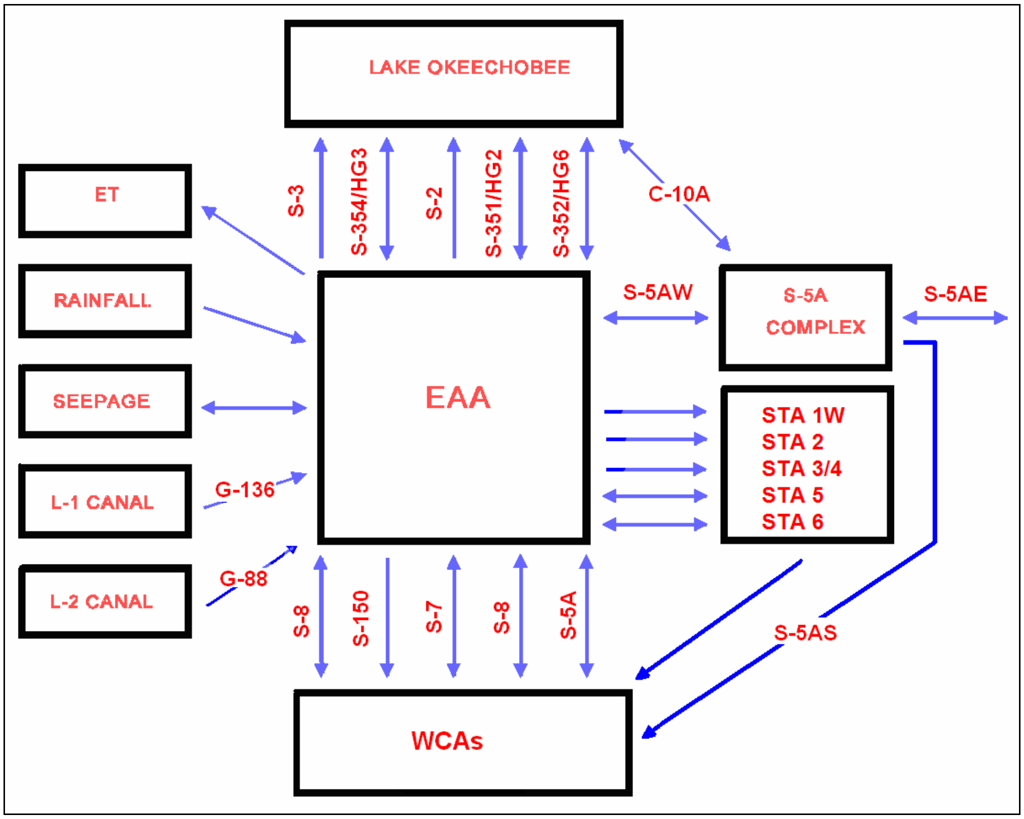

Figure 3.2.1.3 Conceptual Diagram of the Hydrologic System in the EAA as Represented in the SFWMM (Adapted from Abtew and Khanal, 1992).

3.2.2 Simulation of Everglades Agricultural Area Runoff and Demand

The EAA is a system with limited storage capacity. Runoff occurs in times when rainfall exceeds storage capacity and irrigation requirements in the area. Irrigation requirement, on the other hand, is the amount of water in excess of rainfall needed to satisfy evapotranspiration requirements within the EAA. In the soil moisture balance model discussed in the EAA report by Abtew and Khanal (1992), the entire area of the EAA in production was assumed to have a uniform depth to water table equal to 1.5 feet below land surface. This is consistent with the level at which the water table is maintained in the EAA during seepage irrigation, the type of irrigation used for the predominant crop type in the area, sugar cane. Within this narrow band of soil, referred to as the soil column (A in Figure 3.2.2.1), a desired range of moisture contents is maintained. The lower and upper limits of this range (C and D in Figure 3.2.2.1) expressed in terms of equivalent depths of water are SOLCRT and SOLCRNF, respectively.

Therefore, the EAA is simulated in the model such that the natural fluctuation of total soil moisture above the water table is within SOLCRT and SOLCRNF. Also, the water table is maintained at 1.5 feet below land surface.

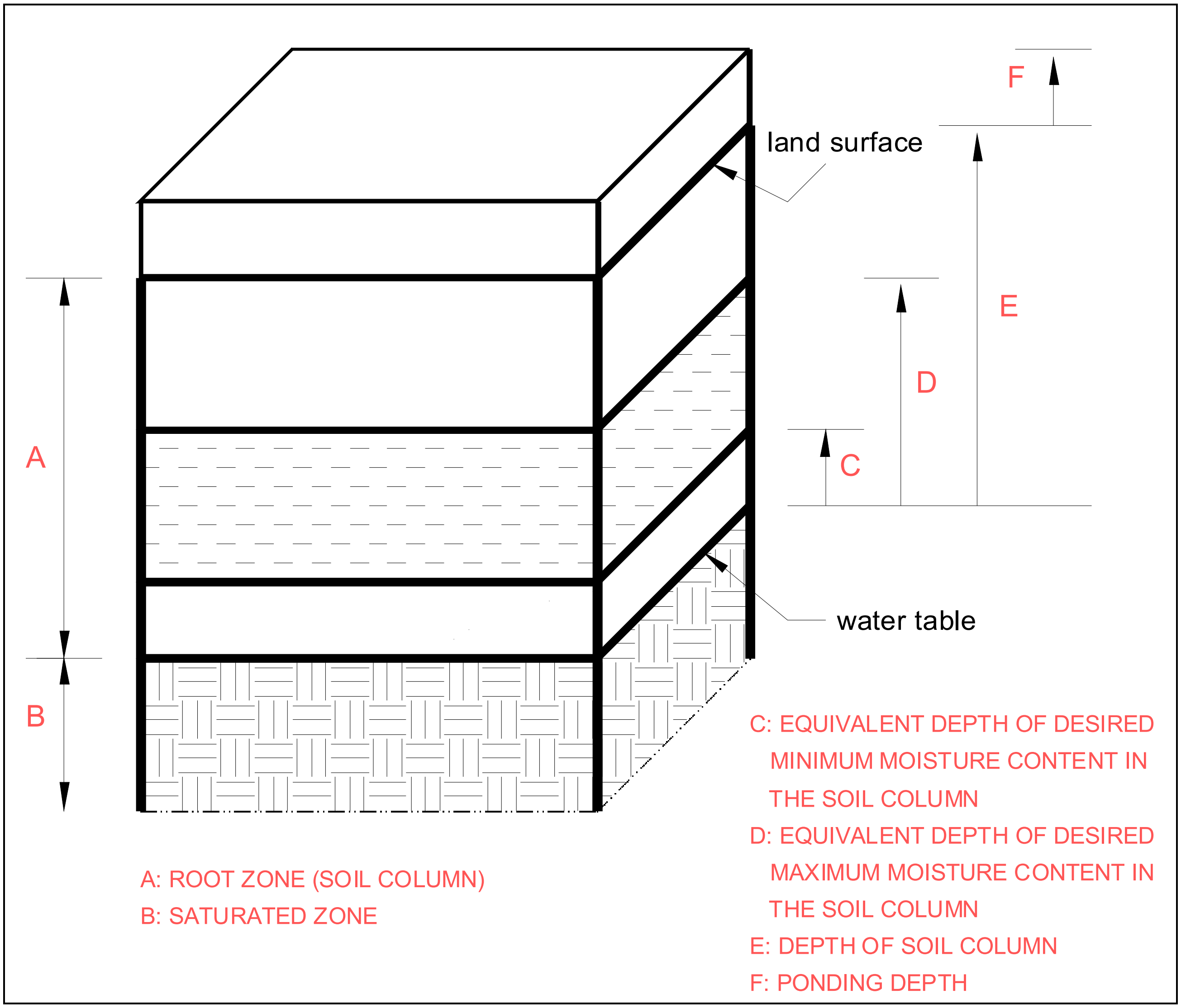

Figure 3.2.2.1 Conceptual Representation of an EAA Grid Cell in the SFWMM

A definition of some pertinent variables used in simulating runoff and irrigation requirements in the EAA is given below:

DPH	=	depth of irrigation requirement;
depth_soil_eaa	=	assumed distance between land surface and the water table; thickness of the soil column; equal to 1.5 ft;
DPTHRNFF	=	potential depth of runoff initially equal to the sum of POND and SOLMX in excess of SOLCRNF;
ELLS	=	land surface elevation relative to NGVD;
ET	=	total evapotranspiration from ponded water, and moisture in the unsaturated and saturated zones;
	=	ETP + ETU + ETS;
fracdph_max	=	ratio of maximum equivalent depth of water that can be stored in the soil column and equivalent depth of desired maximum moisture content in the same soil column; used as a calibration parameter (refer to Chapter 4);

fracdph_min = ratio of minimum equivalent depth of water that can be stored in the soil column and equivalent depth of desired minimum moisture content in the same soil column; used as a calibration parameter (refer to Chapter 4);
GDAR = grid cell area;
GWMAXDP = equivalent depth of water required to fill the storage space below the base of the soil column to the water table plus meeting anticipated saturated zone evapotranspiration;
H = head; location of the water table relative to NGVD;
PERC = water that goes to the saturated zone from ponding and excess moisture in the soil column used to raise the water table up to the base of the soil column;
PERC_IRRIG = water that goes to the saturated zone from irrigation used to raise the water table up to the base of the soil column;
POND = ponding depth;
RAIN = depth of rainfall;
S = storage coefficient; typically 0.20;
SOLCRNF = equivalent depth of desired maximum moisture content in the soil column a calibration parameter that varies with month of year;
= (fracdph_max)(depth_soil_eaa)S;
SOLCRT = equivalent depth of desired minimum moisture content in the soil column; trigger for irrigation requirements to be met from outside sources (e.g., LOK); a calibration parameter that varies with month of year;
= (fracdph_min)(depth_soil_eaa)S;
SOLMDPH = maximum equivalent depth of water that can be stored in the soil column; storage capacity of the soil column;
= (depth_soil_eaa)S;
SOLMX = equivalent depth of soil moisture in the soil column;
VOL_IRRIG = volume of irrigation requirement for an EAA grid cell equal to the product of DPH and GDAR; and
VOL_EXCESS_WATER = volume of excess water that runs off from an EAA grid cell equal to the product of DPTHRNFF and GDAR.

The following sequence of calculations is performed for each EAA grid cell at each time step. Evapotranspiration is calculated first. Assuming unrestricted supply of water at all times, either through available moisture in the root zone, rainfall or irrigation, the theoretical crop requirement is given by:

$$ETMX = (KCALIB)(KVEG)(PET_0) \tag{3.2.2.1}$$

where:
PET_0 = depth of potential evapotranspiration for a reference crop (wet marsh) calculated using SFWMD Simple Method;
KVEG = theoretical crop coefficient which are monthly averaged values; KVEG was based on an earlier study (Abtew and Khanal, 1992). In the EAA, only the predominant crop type: truck crops, sugar cane or irrigated pasture is assigned to each cell; and

KCALIB = adjustment/calibration parameter which varies from month to month; KCALIB was created to take into account differences between modeling approaches, specifically modeling scale, used in the soil moisture balance model by Abtew and Khanal (1992) and the South Florida Water Management Model.

The monthly variation of theoretical crop coefficient KVEG for the three predominant crop types in the EAA was given in Table 2.3.4.3 (land uses 7, 8, and 9). Note that the final/calibrated KVEG values for the EAA correspond to the product of the theoretical KVEG and the adjustment/calibration parameter KCALIB discussed in this section.

Total evapotranspiration depth, on the other hand, is given by:

$$ET_0 = (KFACT)(PET_0) \tag{3.2.2.2}$$

where KFACT is an adjustment factor that takes into account vegetation/crop type and location of the water table relative to land surface. Table 3.2.2.1 shows the adjustment factor KFACT as a function of depth. Note that ETMX corresponds to ET_0 evaluated at land surface down to the depth to shallow root zone. A definition of some variables introduced in Table 3.2.2.1 follows the table.

Table 3.2.2.1 Variation of KFACT in the Equation for Theoretical Total Evapotranspiration as a Function of Depth

Depth from Land Surface to Water Line DWT: water table condition (below ground) PND: ponding condition (above ground)	**Adjustment Factor, KFACT**
DWT ≥ DDRZ	0.0
DSRZ < DWT < DDRZ	(KCALIB)(KVEG)[(DDRZ – DWT) / (DDRZ – DSRZ)]
0.0 ≤ DWT ≤ DSRZ	(KCALIB)(KVEG)
0.0 < PND ≤ OWPOND	(KCALIB)(KVEG) + [KMAX – (KCALIB)(KVEG)](PND / OWPOND)
PND > OWPOND	KMAX

The table variable definitions are as follows:

OWPOND = ponding depth above which open-water ET exists; transpiration by plants submerged at depths equal to or more than OWPOND no longer contribute to evapotranspiration, and evapotranspiration is equal to open-water evaporation; OWPOND is assigned a value of 12 inches in the model;

DSRZ = depth from land surface to the bottom of the shallow root zone; depth below which the root system of a crop will experience increased difficulty in extracting water from the saturated zone; equal to 18 inches;

DDRZ = depth from land surface to the bottom of the deep root zone; depth below which the root system of a crop can no longer extract water from the saturated zone; assumed to be between 36 to 46 inches;

PND = depth of ponding;
DWT = distance of water table below land surface; and
KMAX = conversion factor from PET_0 to open water ET; assumed to be equal to 1.1.

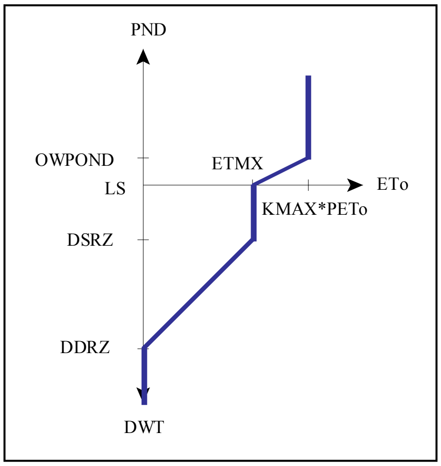

Figure 3.2.2.2 Variation of Total Evapotranspiration, ET_0, as a Function of Depth

Figure 3.2.2.2 is a diagram of the total evapotranspiration as it varies with depth. The actual total evapotranspiration (ET) is the sum of three components: ETS from the saturated zone, ETU from the unsaturated zone, and ETP from free water zone or ponding. The model assumes that evapotranspiration is extracted from the unsaturated zone first, and the free water zone last. Initially, ponding and rainfall are assumed to increase moisture in the soil column. Unsaturated zone evapotranspiration then becomes the lesser value between the theoretical crop requirement [Equation (3.2.2.1)] and the total moisture in the soil.

$$ETU_t = \min(ETMX_t, POND_{t-1} + RAIN_t + SOLMX_{t-1}) \tag{3.2.2.3}$$

The remaining theoretical requirement, $ETMX_t - ETU_t$, if any, will be met from the water table. This amount is limited by the remaining theoretical total evapotranspiration. The anticipated evapotranspiration from the saturated zone is:

$$ETS_t = \min(ETMX_t - ETU_t, ETS_0) \tag{3.2.2.4}$$

where ETS_0 is the theoretical saturated zone ET. It is essentially the same as ET_0 defined at depths below land surface (LS in Figure 3.2.2.2). Evapotranspiration from ponding becomes:

$$ETP_t = \min(ET_0 - ETMX, POND_t) \tag{3.2.2.5}$$

For accounting purposes, the following equalities are assumed for ponding and non-ponding conditions:

1. If ponding exists:
   $ET = ET_0$, $ETU = ETMX$, $ETS = 0.0$, and $ETP = ET - ETU$
2. If there is no ponding:
   ETU from Equation (3.2.2.3),
   ETS from Equation (3.2.2.4), $ETP = 0.0$, and $ET = ETU + ETS$

The soil moisture content expressed in terms of equivalent water depth above the base of the soil column is calculated next:

$$SOLMX_t = SOLMX_{t-1} + POND_{t-1} + RAIN_t - (ETU_t + ETP_t)$$

If the updated soil moisture content exceeds the storage capacity of the soil column, SOLMDPH, ponding will result at the end of the time step and soil moisture have to be reevaluated. Thus:

$$POND_t = \max(\ SOLMX_t - SOLMDPH,\ 0.0\ ) \qquad (3.2.2.6)$$

$$SOLMX_t = SOLMDPH \quad \text{if} \quad POND_t > 0.0 \qquad (3.2.2.7)$$

The potential depth of runoff, DPTHRNFF, equals the ponding depth plus any soil moisture beyond the equivalent depth of the desired maximum moisture content in the soil column, SOLCRNF. (NOTE: SOLCRNF ≠ SOLMDPH).

$$DPTHRNFF_t = \max(\ POND_t + SOLMX_t - SOLCRNF,\ 0.0\ )$$

So far, this amount of potential runoff assumes that the water table is already at 1.5 feet below land surface elevation. An assumption in the simulation of the EAA in the SFWMM is that ponded water and moisture in the unsaturated zone percolates into the saturated zone up to the base of the soil column, if necessary, before runoff actually occurs. DPTHRNFF is reduced by the amount of percolation or the amount of water needed to bring the water table at 1.5 feet below land surface. In other words, if the water table is below the base of the soil column, the potential depth of runoff will be used to fill the available storage in the form of percolation. The concept of maintaining the water table at 1.5 feet below land surface, and the specification of the desired minimum and maximum moisture content (in terms of equivalent depth) above the water table are key modeling techniques used to simulate runoff and quantify irrigation requirements (demands) in the EAA module of the SFWMM.

Actual percolation is the lesser value between what could potentially runoff, DPTHRNFF, and the amount of water necessary to bring the water table up to the base of the soil column, GWMAXDP. Assuming that the water table is below the base of the soil column, GWMAXDP represents the available storage between the base of the soil column and the water table plus anticipated saturated zone ET. It can be calculated as follows. The vertical distance between the water table and the base of the soil column, WT_TO_BSC, is given by:

$$WT\_TO\_BSC_t = (ELLS - SOLMDPH \div S) - H_t$$

Note that SOLMDPH ÷ S is equal to 1.5 ft, and WT_TO_BSC is greater than zero if the base of the soil column is above the water table.

$$EQUIV\_DEPTH\_SOIL\_COL\_TO\_WT_t = \max[\ (WT\_TO\_BSC_t)(S),\ 0\ ]$$

$$GWMAXDP_t = EQUIV\_DEPTH\_SOIL\_COL\_TO\_WT_t + ETS_t$$

$$PERC_t = \min(\ DPTHRNFF_t,\ GWMAXDP_t\ ) \qquad (3.2.2.8)$$

The updated potential depth of runoff becomes:

$$DPTHRNFF_t = DPTHRNFF_t - PERC_t \tag{3.2.2.9}$$

while the remaining storage below the base of the soil column that needs to be filled in from other sources (specifically, via irrigation) is:

$$GWMAXDP_t = GWMAXDP_t - PERC_t \tag{3.2.2.10}$$

It should be noted that $GWMAXDP_t$ can be positive only if $DPTHRNFF_t = 0.0$ after Equation (3.2.2.9). In other words, DPTHRNFF and GWMAXDP are mutually exclusive, i.e., they cannot be non-zero at the same time.

The model assumes that the portion of the potential depth of runoff that comes from ponding percolates below the soil column before soil moisture in excess of SOLCRNF does. Therefore, if the amount of water that percolates is greater than $POND_t$, then, all ponding is assumed to percolate and soil moisture is reduced. $SOLMX_t$ and $POND_t$ are updated within the current time step t:

$$SOLMX_t = SOLMX_t - (PERC_t - POND_t) \tag{3.2.2.11}$$

$$POND_t = 0.0 \tag{3.2.2.12}$$

Otherwise, $POND_t$ is reduced while $SOLMX_t$ remains the same:

$$POND_t = POND_t - PERC_t \tag{3.2.2.13}$$

If, at this point in the algorithm, the updated potential depth of runoff, $DPTHRNFF_t$ in Equation (3.2.2.9), is still positive, it implies that the water table is already at the base of the soil column and no irrigation is required for this EAA grid cell. $DPTHRNFF_t$ will, indeed, leave the grid cell and the final ponding above land surface and final soil moisture in the soil column are computed using the following three equations:

$$SOLMX_t = SOLMX_t + POND_t - DPTHRNFF$$

$$POND_t = \max(SOLMX_t - SOLMDPH, 0.0) \tag{3.2.2.14}$$

$$SOLMX_t = SOLMX_t - POND_t \tag{3.2.2.15}$$

And the volume of excess water leaving the grid cell becomes:

$$VOL\_EXCESS\_WATER = (DPTHRNFF)(GDAR) \tag{3.2.2.16}$$

If, on the other hand, the updated potential depth of runoff, $DPTHRNFF_t$, is zero, it implies that: (1) ponding is zero; (2) irrigation may be required to bring the water up to the bottom of the soil column and/or maintain an equivalent depth of minimum moisture content SOLCRT in the soil column; and (3) the water table may still be below the base of the soil column (NOTE: SOLCRT ≤ SOLCRNF).

The irrigation requirement is calculated next. The total required storage depth for irrigation is:

$$TOTAL\_DEPTH = GWMAXDP + DEPTH\_BELOW\_MIN \qquad (3.2.2.17)$$

The first term in the above equation, GWMAXDP, represents the equivalent depth of water required to maintain the saturated zone. The second term, DEPTH_BELOW_MIN, is the equivalent depth of water required to maintain minimum moisture content in the unsaturated zone. It is calculated as:

$$DEPTH\_BELOW\_MIN = \max(\ SOLCRT - SOLMX_t\ ,\ 0.0)$$

By definition, the depth of irrigation requirement, DPH, is equal to the lesser value between the net theoretical crop evapotranspiration requirement, $\max(ETMX - RAIN_t, 0)$, and the total required storage depth for irrigation.

$$DPH = \min[\ \max(\ ETMX - RF_t\ ,\ 0.0\ )\ ,\ TOTAL\_DEPTH\ ] \qquad (3.2.2.18)$$

The model assumes that irrigation brings the soil moisture content in the soil column (unsaturated zone) up to the minimum level SOLCRT before percolation occurs. Percolation, at this point in the discussion, is the process by which water is introduced below the soil column via irrigation in order to bring the water table 1.5 feet below land surface. Therefore, the anticipated increase in soil moisture in the unsaturated zone, after irrigation, will be equal to the lesser of values between the depth of irrigation requirement and irrigation required to bring the soil content in the soil column to equivalent depth SOLCRT:

$$SOLMX_t = SOLMX_t + \min(\ DPH\ ,\ DEPTH\_BELOW\_MIN\ ) \qquad (3.2.2.19)$$

Finally, anticipated percolation due to irrigation can be calculated as that portion of DPH in excess of DEPTH_BELOW_MIN:

$$PERC\_IRRIG = \max(\ DPH - DEPTH\_BELOW\_MIN\ ,\ 0.0\ ) \qquad (3.2.2.20)$$

For a given EAA grid cell, the volume of irrigation requirement is given by:

$$VOL\_IRRIG = (DPH)(GDAR) \qquad (3.2.2.21)$$

3.2.3 Routing of Excess Runoff

The above calculations are done for all cells in each EAA basin. On any given day, a grid cell may either have excess water or irrigation requirement but not both. The total net excess volume of water for a given basin j is given by the formula:

$$NET\_EXCESS\_VOL_j = \sum_{i=1}^{nnodes_j} \left(VOL\_EXCESS\_WATER_i - VOL\_IRRIG_i \right) \quad (3.2.3.1)$$

where:

j = 1 for Miami Canal Basin;
= 2 for North New River/ Hillsboro Canal Basin; and
= 3 for West Palm Beach Canal Basin.

A positive total net excess volume of water for an EAA basin j is equal to what could potentially leave the basin. Thus, for a given time step, runoff from some cells are used to meet irrigation requirements in the other cells within the same basin and any net excess volume of water (potential excess runoff) can be routed out of the basin and into storage areas such as Lake Okeechobee and the Water Conservation Areas. The intrabasin transfer of the volume of excess water is not done based on the traditional channel routing or overland flow procedures but is performed by direct transfer of water. It is assumed that secondary and tertiary canal systems in the EAA have sufficient capacity to move this volume of water from appropriate cells into cells within the same basin that require irrigation within one time step.

In reality, the system may not be able to remove the entire net excess volume of water from a given EAA basin due to the following constraints:

1. Attenuation and lag effects in the secondary and tertiary canal systems cause actual excess runoff leaving a basin to be less than the potential excess runoff for the same day. Based on a comparison of simulated daily excess water with historical runoff from all EAA basins for the period 1983 through 1990, the actual excess runoff can be calculated as a fraction of the potential excess runoff which, in turn, is equal to the net excess volume calculated in Equation (3.2.3.1). In effect:

$$\text{actual excess runoff} = (\text{FRACT})(\text{NET\_EXCESS\_VOL}) \quad (3.2.3.2)$$

The reduction factor, FRACT, is a fraction that varies with the magnitude of potential excess runoff.

2. The design capacity of outlet structures limits the amount of excess runoff that can be removed from an EAA basin. Table 3.2.3.1 shows the operational constraints used in removing excess runoff for each EAA basin on a daily basis as implemented in the SFWMM. The empirical equations in the table are a result of a statistical analysis of available flow records for the major EAA structures.

Rotenberger Tract and Holey Land, although part of the Miami Canal Basin, are separated from the irrigated areas by levees, and are treated as separate basins in the model. Any net runoff in excess of structure design capacities is returned uniformly to all grid cells within the appropriate basin. Currently, interbasin transfers of runoff within the EAA through the Cross and Bolles Canals are not simulated in the model.

Table 3.2.3.1 Operational Constraints Used in the SFWMM for Removing Excess Runoff from EAA Basins

EAA Basin	Flood Control Back Pumping (BP) to LOK	Routing of Remaining EAA Runoff
Miami Canal Basin	BP = 80% of 7-day running mean daily runoff from basin in excess of 3200 cfs Note: Back Pumping is done through S-3. (S-3 capacity* = 2,600 cfs).	A maximum daily rate of 750 cfs to Holey Land, depending on Holey Land's stage relative to its schedule. The remainder goes to WCA-3A through S-8. (S-8 capacity* = 4,200 cfs).
North New River-Hillsboro Canal Basin	BP = 80% of 7-day running mean daily runoff from basin in excess of 4500 cfs Note: Back Pumping is done through S-2. (S-2 capacity = 3,600 cfs).	10% of runoff goes through S-150 into WCA-3A; 50% of runoff goes through S-7 into WCA-2A (S-7 capacity = 2,500 cfs); and 40% of runoff goes through S-6 into WCA-1 (S-6 capacity* = 2,900 cfs)
West Palm Beach Canal Basin	None	100% of runoff goes through S-5A pumps into WCA-1 (S-5A capacity = 4,800 cfs)

* rounded-off to the nearest 100 cfs

Meeting Irrigation Requirements

If the total net excess volume of water for any EAA basin is negative, then an irrigation requirement for the basin has to be met from storage areas outside the basin. Currently, only Lake Okeechobee is used to meet irrigation requirements in the EAA. Deliveries to meet irrigation requirements are limited by conveyance capacities of the primary canals in the EAA. Likewise, water shortage policies as outlined in Section 3.3 may be imposed during periods of low Lake levels. Any irrigation requirement not met, due to conveyance limitations and/or limits set by management policies, will result in a uniform reduction in water levels for all grid cells in the appropriate destination EAA basin(s). On a given day, all EAA basins may not have irrigation requirements simultaneously. The discussion of EAA canal conveyance is given next.

EAA Canal Conveyance

Deliveries from Lake Okeechobee through the infrastructure in the EAA to the Everglades and/or LEC are subject to constraints, as discussed in the following sub-sections.

Downstream Constraints in the Everglades. If stages in the Everglades are sufficiently high that releases from Lake Okeechobee could do further harm, releases are discontinued. The conditions for which releases from the Lake for environmental water supply or flood control are discontinued are dictated by the simulated management criteria for both the Lake and the EPA. Examples of such constraints would be stage-based rainfall driven operation targets for the EPA (to be discussed in Section 3.4) and checks against criteria as outlined in Part 1 of the WSE decision tree operations for Lake Okeechobee (as shown in Section 3.1).

Conveyance Constraints on Releases from Lake Okeechobee to Everglades and/or LEC. In the EAA, canal constraints are not just a function of design capacities and hydraulic conductivities, but also a function of day-to-day operational concerns. An analysis of historical flows through the major EAA canals (Miami, North New River, Hillsboro and West Palm Beach) reveals that the actual amount of regulatory flows released from the Lake and the actual magnitude of agricultural runoff removed from the EAA were rarely close to the design capacity of the canals (Trimble, 1995b). In order to establish realistic allowable flows through these canals consistent with historical data, a seasonal average percentage of design discharge (Q_{design}) is used to define each EAA canal conveyance capacity in the model (Table 3.2.3.2). Due to the nature of wet season rainfall which often occurs in sudden heavy outbursts, the percentages associated with the wet season are stricter than those for the dry season. Lateral inflows (runoff from EAA basins) are pumped as necessary into the major canals from farm-scale pumps. Although the lateral inflows are greater during the wet season, they also occur in dry seasons. The values shown in Table 3.2.3.2 are reevaluated from time to time by analyzing more recent historical flow data at the major inlet and outlet structures in the EAA.

Table 3.2.3.2 Allowable Percentage of Design Discharge through the Major EAA Conveyance Canals

EAA Conveyance Canal	Q_{design} [cfs]	Dry Season Percentage	Wet Season Percentage
Miami Canal	2,000	75%	50%
NNR-Hillsboro Canal	2,400	80%	50%
West Palm Beach Canal	950	65%	50%

There are several type of uses for the canal conveyance and a priority has been established where canal constraints are limiting factors. The priority of flow volumes in using EAA canal/structure conveyance is as follows:

1. EAA basin runoff/demand;
2. Water supply deliveries to STAs;
3. Runoff from 298 drainage districts;
4. Water supply to Big Cypress Seminole Reservation and Holey Land WMA;
5. Environmental (rain-driven) water supply to Everglades and water supply to the LEC;
6. BMP Makeup water;
7. Excess water to proposed reservoirs, if applicable;
8. Regulatory releases from Lake Okeechobee to WCAs.

Conveyance for the major EAA canal systems for flow through are calculated each time step based upon the HEC-2 look up tables for the "neutral case" condition (USACE, 1990). The neutral case refers to the flow through capacity during no lateral flow conditions (no runoff *and* no demand) within the EAA. Given an EAA conveyance canal with upstream and downstream controls, there exists a unique combination of upstream stage, downstream stage and canal profile that responds to the maximum flow of water from the source (LOK) to the destination (WCA or STA). The maximum headwater stage in the canals for flow through releases from Lake Okeechobee to STAs, WCAs and/or LEC is assumed to be 12.0 ft NGVD.

The percentages from Table 3.2.3.2 are then applied to Lake water pass-through/flow-through calculations in the following manner. During the wet season, when Lake stage is above regulation, the maximum amount of water Q_{max} that can be released from the Lake and delivered south to the WCAs via EAA canals can be calculated as

$$Q_{max} = \min[\text{neutral\_case}\ ,\ (\text{percent\_wet})(\text{design\_discharge})] - (\text{runoff} + \text{existing flow from LOK}) \tag{3.2.3.3}$$

Flow calculations for the neutral_case are defined a little later in this section. Flow-through capacity during water supply conditions, on the other hand, can be defined as

$$Q_{max} = \min[\text{neutral\_case} - (\text{demand} + \text{existing flow from LOK})\ ,\ (\text{percent\_wet})(\text{design discharge})] \tag{3.2.3.4}$$

During the dry season, two other empirical relationships can be defined for regulatory release and water supply release conditions:

$$Q_{max} = \min[\text{neutral\_case} - (\text{runoff} + \text{existing flow from LOK})\ ,\ (\text{percent\_dry})(\text{design\_discharge})] \tag{3.2.3.5}$$

and

$$Q_{max} = \max\{\ \text{neutral\_case} - [\ \text{demand} + (\text{existing flow from LOK})\ ]\ ,\ 0.0\ \} \tag{3.2.3.6}$$

It must be emphasized that the above formulas for computing maximum allowable flows through the major EAA conveyance canals are empirical in nature. They reflect the field operators' preferences as they adapt to real day-to-day hydrologic conditions. Therefore, Equations (3.2.3.3) through (3.2.3.6) include the subjectivity involved in operating major structures in the EAA.

The neutral_case refers to the pass-through/flow-through capacity during no lateral flow conditions (no runoff and no demand) within the EAA. Given an EAA conveyance canal with upstream and downstream controls, e.g. S-354/Miami Canal/S-8, there exists a unique combination of upstream stage (S-354_HW), downstream stage (S-8_TW) and canal profile (along the Miami Canal) that corresponds to the maximum flow of water from the source (Lake Okeechobee) to the destination (WCA-3A). To determine the maximum flow for each major canal reach, a steady-state backwater analysis was conducted (Gee and Jenson, 1995) and the rating curve information was identified for all types of configurations structures that would occur for the same canal reaches. Then a separate solution routine was written for canals in the EAA where neutral case conveyance calculations are performed. Figure 3.2.3.1 shows all types of configurations where neutral case conveyance calculations are performed in the model. Italicized words refer to the specific program subroutines or functions that perform the calculations. For example, given Lake stage and S-8 pump headwater, a subroutine solving the configuration like Figure 3.2.3.1(c) would be executed when the pass-through discharge along the existing Miami canal is required. If the canal configuration is modified to include an intervening diversion structure (e.g. STA3/4 flows) along the Miami canal, then the subroutine solving the configuration like Figure 3.2.3.1(d) would be executed. The key assumption in this approach is that a known water surface profile provides a unique discharge through a specific canal reach-structure configuration. Since the model is not concerned with what happens internally within the EAA, specification of headwater (Lake stage) and tailwater (downstream of EAA) conditions is sufficient to determine neutral_case flows. The model adjusts the headwater and tailwater conditions at appropriate canal reaches and intermediate structures in response to runoff or demand conditions in the EAA.

In summary, the neutral_case (no-runoff or no-demand condition) discharges or conveyance capacities are obtained in the model as a series of look-up tables generated from multiple HEC-2 runs for each canal, covering a wide range of flows, and upstream and downstream stages. Table 3.2.3.3 lists some properties of the nine EAA canal reaches where look-up tables were generated for and used in calculating conveyance capacities through the EAA.

Table 3.2.3.3 Some Physical Properties of the Eight EAA Canal Reaches Used in Calculating Conveyance Capacities through the EAA

EAA Canal	Upstream Reference Stage	Downstream Reference Stage	Length [mi]
Miami	LOK stage	S8_TW	26.2
North New River	LOK stage	S7_TW	28.6
Hillsboro	S351_TW	S6_HW	23.7
West Palm Beach	S352_TW	S5A_HW	20.8
Miami* (upper reach)	S354_TW	S8NEW_HW	19.3
North New River* (upper reach)	S351_TW	S7NEW_HW	24.6
North New River* (lower reach)	S7NEW_TW	S7_HW	4.0
Miami* (lower reach)	S8NEW_TW	S8_HW	6.9

*Refers to future base scenario with proposed Stormwater Treatment Areas in operation, and the Miami and North New River canals are both split into upper and lower reaches. NOTE: Variables in parentheses are known or fixed values.

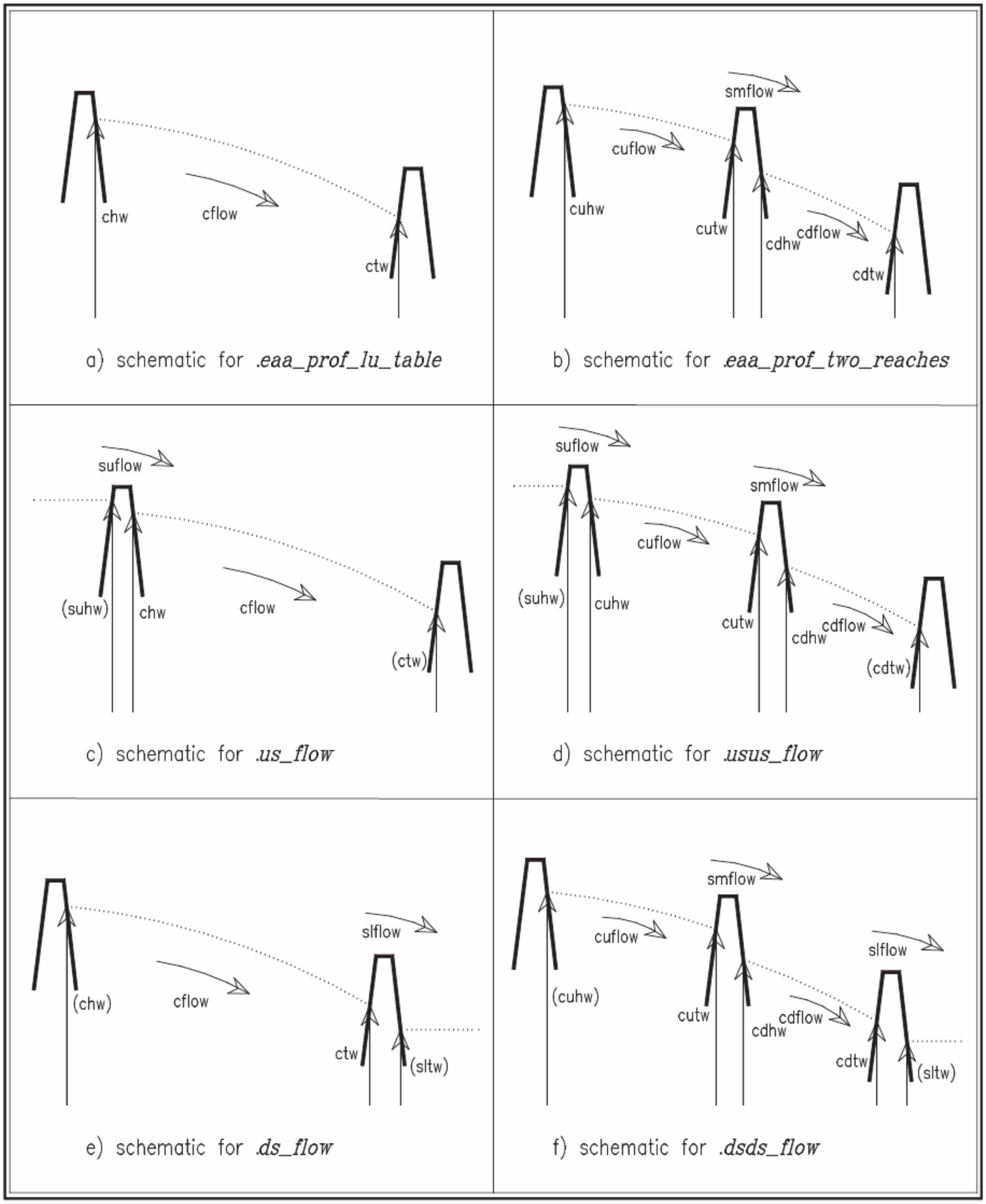

Figure 3.2.3.1 Canal-Structure Configurations Used in Calculating Canal Conveyance Capacities for the EAA Algorithm in the SFWMM

Conveyance Constraints on Water Supply Releases to Everglades and/or LEC. When making water supply deliveries, there are additional operational concerns. The following discussion refers to the operations related to environmental deliveries (refer to Section 3.4) with a full build-out of the STAs. Deliveries for Best Management Practices and makeup water are handled separately from the water supply deliveries. Environmental releases made from Lake Okeechobee (LOK) through the major EAA canals for water supply purposes are two fold: To deliver water to the Everglades (WCAs/ENP) when stages at specific target locations are sufficiently low; and to deliver water to LEC service areas when canal stages in WCAs are at or below floor elevation or marsh stages (if applicable) at specific locations in WCAs are below criteria for minimum flows and levels.

The maximum possible water supply release from Lake Okeechobee through each major EAA canal is defined by the following:

$$\text{max\_flow\_through\_ws} = \max[\ (\text{CNCC})(\text{CF}) - (\text{other\_flows})\ ,\ 0.0]$$

where:

- CNCC = current neutral case capacity based on HEC-2 lookup tables;
- CF = EAA canal conveyance multiplier (1.0 represents the current system, greater than 1.0 represents increased capacity); and
- other_flows = EAA_canal_basin_runoff_or_demand + LOK_ws_to_sta + LOK_ws_to_Big_Cypress_Seminoles + LOK_ws_to_Holeyland_WMA

Decisions must be made in the SFWMM in the way demands are being met when demands on Lake Okeechobee exist in both the Everglades and the LEC service areas. Decisions are made on volumes of water treated by STAs that go to meet environmental needs in the Everglades and volumes of water untreated that go directly to meet LEC demands. The flowchart shown in Appendix F2 depicts the flexibility in the SFWMM for managing Lake Okeechobee releases and/or EAA basin runoff in meeting Everglades and/or LEC service demands.

In order to establish realistic allowable flows through these canals consistent with historical data, a seasonal average percentage of design discharge (MFC) is used as an additional limit to conveyance capacity. If needs exist in the Everglades, the maximum flow to the Everglades from Lake Okeechobee is as follows:

1. During wet season and when runoff from EAA canal basin is greater than zero:
   $$\text{max\_LOK\_to\_Glades} = \max\{\ \min[\ (\text{CNCC}_{PSTA})(\text{CF})\ ,\ \text{oper\_capac}] - \text{other\_flows}\ ,\ 0.0\}$$
2. During the dry season or when runoff from EAA canal basin is zero:
   $$\text{max\_LOK\_to\_Glades} = \min(\text{CNCC}_{PSTA} - \text{other\_flows}\ ,\ \text{oper\_capac})$$

where:

- CNCC_{PSTA} = neutral case capacity of canal when water is pumped into STA since the water going to meet environmental needs is treated by STA oper_cap:
  a. Under current conditions (with CF = 1.0):
     $$\text{oper\_capac} = (\text{CNLD}_{cap})(\text{MFC})$$
  b. For future proposed conditions (with CF > 1.0):
     $$\text{oper\_capac} = (\text{CNLD}_{cap})(\text{MFC}) + [\ \text{CNLD}_{cap}\ (\text{CF} - 1.0)\ ]$$
     The additional capacity due to increased conveyance goes to meet Everglades needs (MFC is not applied to this additional capacity);
- CNLD_{cap} = current design capacity for canal system;
- MFC = maximum fraction of current design capacity delivered from LOK to Everglades.

If there are LEC service area demands only, then the release from Lake Okeechobee is as follows:

flow_through_ws = min(max_flow through_ws , LEC service area demands met by LOK)

3.2.4 L8 Basin, S236 Basin and 298 Districts

The discussion to this point of irrigation requirements and runoff routing within the distributed mesh portion of the SFWMM has focused on the primary EAA basins. A similar methodology is applied to the L8 and S236 Basins and to the 298 Districts (also known as Water Control Districts), located on the southeastern rim of Lake Okeechobee (refer to Figure 3.2.1.1). These basins follow the same methodology for estimation of net supplemental irrigation requirement and excess runoff as that previously outlined in this section. All three of these basins can receive water supply from Lake Okeechobee. Runoff routing options are handled differently, however. Excess water from the L-8 Basin can be sent to Lake Okeechobee or to the S-5A complex on the northern edge of the Everglades Protection Area where it can be diverted into either WCA-1 or LECSA-1. The S236 Basin runoff can be directed either into the Lake or to the Miami canal if Stormwater Treatment Area 3&4 is being simulated (additional detail provided in Section 3.2.5). For the 298 districts, the majority of runoff is returned to the Lake. Additional options exist within the model to redirect fractional contributions of runoff into the appropriate canal basins (West Palm Beach, North New River, and Miami River Canals) as shown in Table 3.3.8.1. These options are used in routing water associated with operational criteria associated with the Everglades Construction Project (ECP).

Table 3.2.4.1 Fractional Contributions of 298 Districts to Major EAA Canals

298 District Name	Pump Station	Receiving Canal	Max pump size [cfs]	Fraction of 298 Total RO*
South Shore Drainage Dist.	SSDD	Miami	178	19%
South Florida Conservation Dist.	SFCD P5E	Miami	120	16%
East Beach Water Control Dist.	EBWCD #3	West Palm Beach	338	36%
East Shore Water Control Dist.	ESWCD PS2	Hillsboro	439	29%

* Remaining fraction of Total RO flows into Lake Okeechobee

3.2.5 Everglades Agricultural Area Reservoirs and Storage Components

Water-holding facilities or reservoirs serve a variety of functions within the EAA. The Holey Land can be considered as an above-ground reservoir that acts as a wetland preserve. Additional examples of above-ground reservoirs in the EAA are the Stormwater Treatment Areas (STAs) whose function is to improve the water quality of runoff generated from the EAA as well as releases from Lake Okeechobee. Proposed EAA Storage Reservoirs are examples of above-ground reservoirs which are intended to store Lake water or EAA runoff for later use. These uses include: 1) to meet EAA water supply needs (primarily irrigation) during drier times within the EAA and 2) to pass Lake Okeechobee regulatory flows to the EPA. The Holey Land and partially constructed STA reservoirs currently exist in the EAA, while design and construction work on EAA Storage is underway.

In general, the means by which reservoirs are modeled is discussed in Section 3.6. The following text will describe how the STA storage features are handled in the vicinity of the EAA as a means of showing the capabilities of the SFWMM. The objectives of STAs (Figure 3.2.5.1) are summarized as follows:

1. To reduce long-term average concentration of total phosphorus from EAA runoff to the Everglades Protection Area to an ultimate goal of 10 ppb.
2. To restore the hydroperiod in the northern areas of WCA-2A and WCA-3A.
3. To increase quantity and improve quality of water retained in the Everglades system through redirection of runoff from C-51W Basin.
4. To restore the hydroperiod in the Rotenberger Tract with water of suitable quality.
5. To reduce localized water quality problems in Lake Okeechobee associated with discharges from special drainage districts adjacent to the Lake such as the 298 Districts.

In order to illustrate the level of complexity that can be obtained using the model, Figure 3.2.5.2 shows a schematic of how the SFWMM depicts the operation of the system within and around the EAA area after all proposed STAs are in place (circa 2010 Base Condition).

The specific operation of STAs within any given model simulation will vary with other options modeled (e.g. Rain Driven Operations where optimal environmental deliveries to the EPA are considered). However, the general assumptions used in implementing STAs in the SFWMM are:

1. A mass balance approach using minimal input data is used in calculating discharge in and out of STAs. These discharges are subject to structure and canal conveyance capacity constraints.
2. EAA Best Management Practices when included are simulated by increasing the upper limit of the soil moisture storage in the unsaturated zone for the cells in the EAA. This maximum is determined by trial and error.
3. STAs can be treated as multi-compartment reservoirs.
4. In general, the operational water depths are as follows: minimum depth = 0.5 ft; desired mean depth = 2.0 ft; depth at which outflow begins = 1.25 ft; and maximum depth = 4.5 ft.
5. Water supply releases from Lake Okeechobee to LEC bypass STAs and are, thus, untreated.
6. Inflows vary by location and condition. All inflows are subject to canal conveyance capacities and/or structure capacities.

A summary of the general operating considerations for STAs in the EAA is given in Table 3.2.5.1.

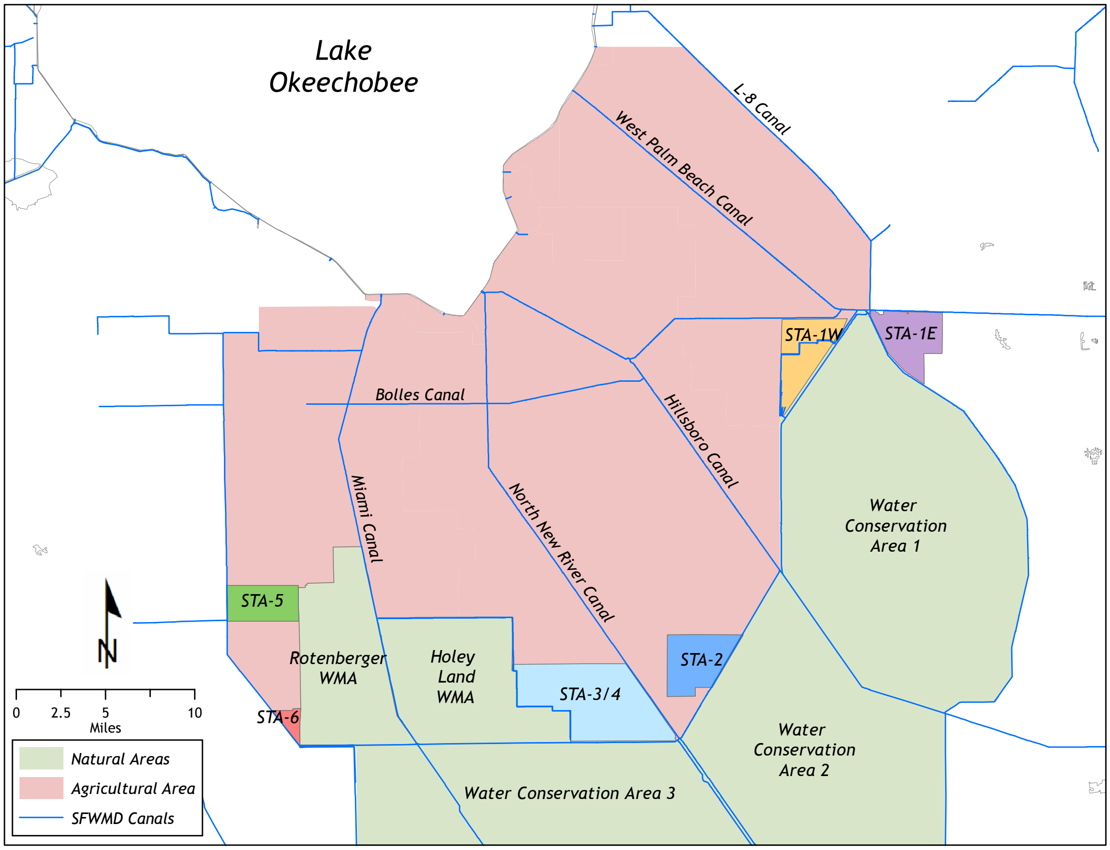

Figure 3.2.5.1 Location of Stormwater Treatment Areas

Table 3.2.5.1 General Operating Considerations for STA-type Reservoirs in the EAA Simulation within the SFWMM

Purpose	Source of Water	Rule for Outflow
Stormwater treatment to reduce phosphorus loading into Everglades Hydroperiod enhancement in WCAs by improvement of volume, timing, and distribution of flow to the Everglades	EAA or other basin runoff LOK regulatory releases LOK environmental water	Regulate outflow such that average depth of water in the Stormwater Treatment Area is approximately equal to 1.25 to 2.0 ft

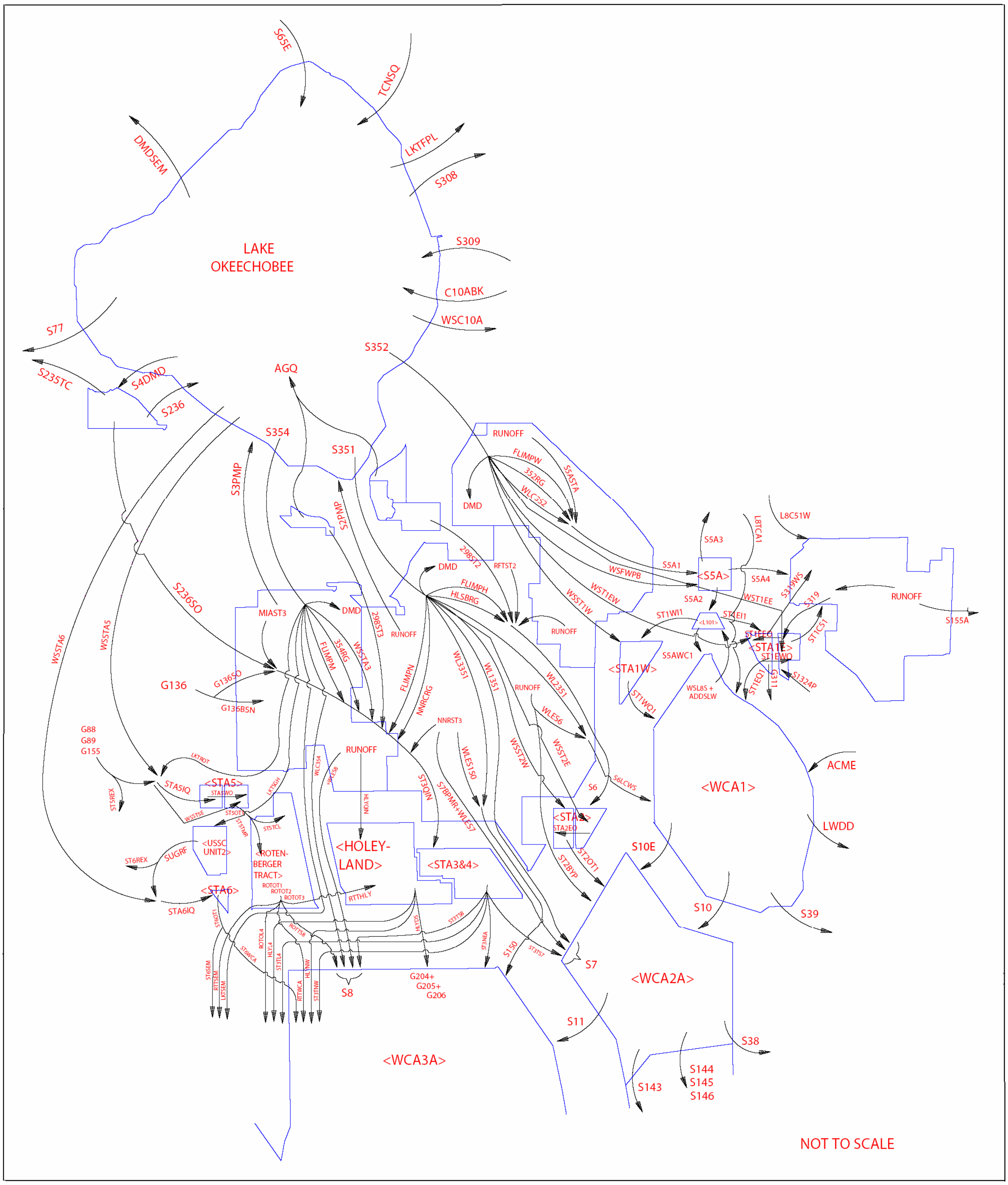

Figure 3.2.5.2 Flow Distribution within and Around the EAA with STAs Fully Constructed

Two options exist in the SFWMM that affect the volume of water treated in STA-3&4, STA-2 and STA-1W. These options refer to the way demands are being met in the Everglades and urban areas. The operations of Lake Okeechobee, EAA, Water Conservation Areas, and Lower East Coast are closely related. Although this section focuses on the EAA, a discussion of some operational rules applicable to the WCAs as well as the Lower East Coast may be necessary at this point in order to explain various options in the model. These options are:

1. "No Priority" Option:

   Under this option, the Everglades will receive (for environmental restoration purposes) all available EAA runoff ahead of the Lower East Coast (for water supply purposes) by virtue of the Everglades' closer proximity to the EAA. The amount to be delivered to the Everglades is limited by the canal conveyance capacities within the EAA as well as operational constraints associated with intervening retention/detention areas such as STAs, if any. Of course, such deliveries will only occur in the model if some stage (or flow) targets are defined by the user for the Everglades; otherwise, all available EAA runoff will be used to meet water supply needs in the LEC.

   The first source of water that meets LEC demands are the Water Conservation Areas. If the runoff generated from the EAA exceeds the remaining LEC demands after the appropriate Water Conservation Area has made its release, all EAA runoff is pumped into the appropriate STA, subject to conveyance constraints. EAA runoff in excess of the STA pump capacity and conveyance capacities within the EAA bypasses the STAs, remains untreated, and is still routed south to alleviate flooding within the EAA.

   If the runoff generated from the EAA is less than or equal to the remaining LEC demands, i.e. after the appropriate WCA has made its release, all EAA runoff bypasses the appropriate STA and is subject to EAA conveyance constraints. Water sent south to meet LEC Service Areas demands is all untreated.

2. Everglades/LEC Priority Option:

   In this option, the user specifies a fraction, FRCT, of the total volume of water available from EAA runoff that will be used directly, i.e., untreated, to meet LEC service area demands as required. This fraction can range from 0.0 to 1.0; environmental demands get priority with a fraction equal to 0.0 while LEC service area demands get priority with a fraction equal to 1.0. In general, what bypasses the STAs and meets LEC service area demands equals FRCT multiplied by the total available water. Conversely, what gets treated by the STAs and meets environmental demands equals (1.0 – FRCT) multiplied by the total available water.

If an STA and a non-STA reservoir both exist in same EAA basin, the model assumes that the non-STA reservoir receives excess runoff/Lake Okeechobee regulatory releases first; the remainder of the excess water goes to the STA reservoir for treatment.

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